KATHOLIEKE UNIVERSITEIT BRABANT
TILBURG UNIVERSITY
POSTBOX 90153
5000 LE TILBURG
THE NETHERLANDS

[redacted]

DEPARTMENT OF ECONOMICS

RESEARCH MEMORANDUM

PRODUCTIVITY, LABOUR FORCE PARTICIPATION AND THE SOLOW GROWTH MODEL

R3

Anton van Schaik

FEW 539

Labour Supply
Labour Productivity

Refereed by Prof.dr. Th.C.M.J. van de Klundert

Productivity, Labour Force Participation and the Solow Growth Model

Anton van Schaik

Professor of Economics
Tilburg University
P.O. Box 90153
5000 LE Tilburg
The Netherlands

Summary

International comparable data of Maddison and Summers and Heston show a negative relation between labour productivity and labour force participation. This relation is here incorporated in the Solow growth model. A cross-section analysis of 95 countries describes about 90% of the international variation in income levels in a satisfactory way.

February 1992

Productivity, Labour Force Participation and the Solow Growth Model

1. Introduction

Maddison's Phases of Capitalist Development was published in 1982. Among economists this book has received much attention, especially after Baumol (1986) referred to it in an article on the convergence of welfare in the richest countries since 1870. Recently, Maddison (1989) has updated the internationally comparable data on GDP per working hour in 16 high-developed countries. These are summarized here in the upper part of table 1. The figures in brackets show the ranking of countries in terms of productivity. It can be seen that in the first half of this century the productivity gap with the United States has grown, whereas after 1950 all countries have come into a stage of catching up with the USA. In this international productivity contest, Belgium for instance moved to the second position, whereas the Dutch economy on average remained in its place.

Table 1

The lower part of table 1 gives Maddison's labour force participation rates for the same set of countries. These rates show some remarkable tendencies. In Canada, the USA and the Scandinavian countries, the participation rates have increased, whereas in Belgium and France the participation rates clearly have decreased. In other countries, such as the Netherlands, the participation rates did not change very much. Thus, by putting the tendencies of both parts of the table together a negative relationship between productivity and participation is showing up[1].

This article deals with the question, how, for a broad sample of countries, the international variation in productivity is related to that in labour force participation. Section 2 examines the recent dataset of Summers and Heston (1991), which displays internationally comparable economic time series covering a large number of countries. These figures also point at a negative relation between productivity and participation. Section 3 supplements this relation with the variables prescribed by the Solow growth model. This model describes nearly 90% of the international variation in productivity. For certain reasons however the standard model must be rejected. Section 4 introduces the Solow model augmented with human capital, as suggested by Mankiw, Romer and Weil (1990). The rate of investment in human capital is approximated by the ratio between a variable describing the educational level and the participation rate. This leads to the conclusion that the augmented model, embodying the negative relation between productivity and labour force participation, is consistent with the international variation in productivity.

2. The data of Summers and Heston

The Summers and Heston dataset covers 138 countries for the period 1950-1988. For a number of countries the series start in 1960. That is why we only use the series from 1960 onwards. The number of countries has been reduced from 138 to 95 for several reasons. The main oil producing countries have been left aside, because productivity in these countries can't be traced back to production circumstances prevailing in the other countries. The availability of data according to the supplementary data set of Barro

(1991) on for instance the degree of schooling also plays a role in restricting the sample. In addition countries with a relatively small population size, such as Luxembourg and Iceland have been omitted.

Table 2 summarizes the relevant information. The countries are classified according to their productivity levels in 1985[2]. Productivity is defined as GDP (Y) per worker in the labour force (L), where GDP is in 1985 international prices.

Table 2

The table distinguishes 5 groupes of 19 countries. The bottom line reports the figures for all 95 countries together. The classification implies that group I comprises the richest and group V the poorest countries. The columns show the avarage values of respectively the growth rate of labour productivity (G), the growth rate of population (π), the growth rate of the labour force (GL), the investment rate in physical capital (σ_k), the investment rate in human capital (σ_h), the participation rate in 1960 (P60) and the productivity level as a percentage of US-productivity in 1960 and 1988 (CU60 and CU88). The figures have not been weighted with the size of the countries. The measurement of investment in human capital will be discussed below.

The table expresses the well-known fact that the rate of investment is lower and population growth is higher if a country is poorer. (The only exception is population growth in group V, which is below that of group IV.) Further it appears that the rich and sub-rich countries exhibit nearly the same productivity growth and are catching up with the USA. However, the relative position of group III vis-à-vis group II hardly has changed, whereas the position of II vis-à-vis I has worsened somewhat. The poor countries are clearly put back during the considered period (1960-1988).

In the Summers and Heston dataset, the participation rate is defined as the ratio between the labour force and total population, both expressed in persons. In table 2, the difference between GL and π thus describes the change of the participation rate over the period 1960-1988. It appears that for the "world" as a whole, labour force participation has diminished sligthly. This is the net result of increasing participation rates in the rich and sub-rich countries on the one hand and decreasing participation rates in the poor and poorest countries on the other hand.

As said above we shall deal with the question, how the international variation in productivity is related to the international variation in labour force participation. A first investigation points at a significant negative relation between productivity and participation in a cross country regression (OLS) for the sample of 1960:

$$\ell n\frac{Y}{L}(60) = \underset{(-4.30)}{-1.72}\ \ell nP(60) + \underset{(9.85)}{14.60} \qquad \bar{R}^2 = 0.16 \tag{2.1}$$

The number of countries is 95. The numbers between brackets are t-values. The dependent variable is labour productivity in 1960. This is "explained" here for about 16% by the participation rate in 1960. In addition, the cross sectional relation between productivity in 1988 and the participation rate in 1960 also appears to be significant:

$$\ell n\frac{Y}{L}(88) = \underset{(-4.45)}{-2.02}\ \ell nP(60) + \underset{(9.63)}{16.21} \qquad \bar{R}^2 = 0.17 \tag{2.2}$$

However, the relation between productivity and participation is completely absent when only the year 1988 is considered:

$$\ell n\frac{Y}{L}(88) = \underset{(0.35)}{0.21}\ \ell nP(88) + \underset{(3.72)}{7.97} \qquad \bar{R}^2 = 0.00 \tag{2.3}$$

Thus, the first impression is that the participation rate of 1960 could be a part in describing the international variation in productivity in both the first and the last year of the sample. This does not hold for the participation rate in 1988. We will argue that the latter might be traced back to the fact that most countries in 1960 were farther from the steady state than in 1988.

3. The Solow model

3.1 The steady state

The Solow growth model starts from a lineair homogenous production function with labour-saving technical progress. The Cobb-Douglas function is an example:

$$Y(t) = K(t)^{\alpha}N(t)^{1-\alpha}, \text{ where } 0<\alpha<1 \tag{3.1}$$

K is the stock of physical capital and N the number of effective units of labour. (From now on the time subscript "t" will be omitted for convenience.) Both inputs are paid their marginal products. Effective labour is defined as the product of population (POP), the participation rate (P) and an index for the level of technology (A):

$$N = A^{*}P^{*}POP = AL, \text{ where } A = A(0)e^{\rho t} \text{ and } POP = POP(0)e^{\pi t} \tag{3.2}$$

Population grows exogenously at rate π and technology at rate ρ. The labour force is the product of population and the participation rate: L=P*POP.

Expressed in effective units of labour the production function is:

$$y = k^{\alpha}, \text{ with } y = Y/N \text{ and } k = K/N \tag{3.3}$$

Output per effective unit of labour (y) will further be called "output-intensity" and the stock of capital per effective unit of labour "capital-intensity". It is important to distinguish output-intensity (y) from labour productivity (Y/L), because only the latter can be deduced from empirical data.

The standard Solow model assumes an exogenous labour supply. In this case the accumulation equation reads as[3]:

$$\frac{dk}{dt} = i - gk \tag{3.4}$$

The gross rate of growth g $(=\delta+\pi+\rho)$, which comprises the depreciation rate δ, is also exogenous. The model is completed with the consumption function (Solow, 1956):

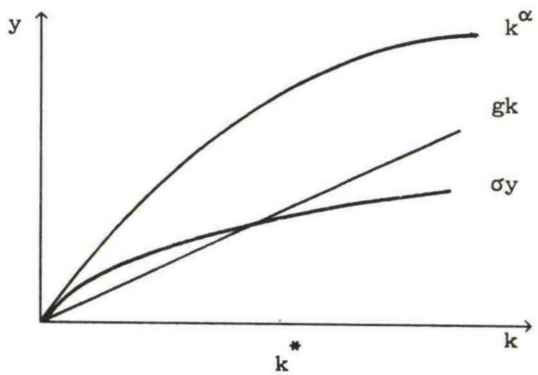
$$c = (1-\sigma)y, \text{ so that } i = \sigma y, \text{ as } y = c + i \tag{3.5}$$

The savings rate σ is exogenous. Using (3.5), the accumulation equation is expressed in the capital-intensity as:

$$\frac{dk}{dt} = \sigma k^{\alpha} - gk \tag{3.6}$$

In the steady state (dk/dt=0) output (Y), the stock of capital (K) and effective labour (N) grow with the sum of population growth (π) and technical progress (ρ). The savings rate only determines the level of the steady state. The Solow model has the well-known property that the steady-state solution is stable in the sense that any dynamic path from arbitrary initial conditions converges through time to a steady state with constant capital-intensity.

Figure 1 The Solow Growth Model



The Solow model predicts a higher steady-state output-intensity (y) when the savings rate is higher and/or population growth is lower. Figure 1 shows the (world)production function (k^{α}), which is assumed to be identical for all countries. In contrast savings (σy) and steady-state investment (gk) are country-specific, because σ and g differ between countries. Thus each country has its "own" steady state, determined by the equality of savings and steady-state investment.

3.2 Estimation

The main parameter of the Solow model to be estimated is α, the share of capital in income. The empirical specification of the model follows from the log-linear version of the production function, after substituting the steady-state capital-intensity into it. The latter can be deduced from the accumulation equation (3.6):

$$k^{*} = (\sigma/g)^{1/(1-\alpha)} \tag{3.7}$$

Substituting (3.7) into (3.3), taking logs and rearranging terms results in:

$$\ell n \frac{Y}{L} = \ell n\ A(0) + \rho t + \frac{\alpha}{1-\alpha} \ell n\sigma - \frac{\alpha}{1-\alpha} \ell n g \tag{3.8}$$

Given marginal-productivity theory, the model not only predicts the signs but also the values of the coefficients. If for instance $\alpha=1/3$, the model implies an elasticity of labour productivity with respect to the rate of savings of 0.5 and an elasticity with respect to the growth rate of -0.5.

Following Mankiw et al. (1990), it is assumed that population growth is country-specific, whereas $\delta+\rho$ is some fixed number, say 5%, for all countries. The term A(0) not only represents technology, but also institutions, climate and so on. It is assumed that:

$$\ell n A(0) = a + \varepsilon, \text{ where a constant and } \varepsilon \text{ country-specific}$$

According to (3.8) the dependent variable is the level of labour productivity in a year, for which it is assumed that all countries are in their steady states or that deviations from the steady state are random. The explanatory variables are the steady-state savings rate and population growth. Thus the empirical problem is to gather data for Y/L, σ and π, which are representative for steady growth. Mankiw et al. (1990) approach Y/L by the figures for the last year of their sample, namely 1985. The independent variables are the rate of investment averaged over 1960-1985 as an appromixation for the savings rate and the average rate of growth of the working-age population as an appromixation for population growth.

These choices are questionable. In the first place it seems to be impossible to find a certain year, for which it may be assumed that all countries are in steady growth. In the second place the participation rates are changing and diverging strongly in the world (see table 2)[4]. The international variation in labour force participation not only can be traced back to social-cultural and demografic factors, but also to reactions of labour supply to changes in real wages and real wealth during the adjustment to the steady state (Boggess, 1983). In the steady state the models with an exogenous respectively endogenous labour supply may work out the same in the end (Bhasin, 1991), but out of the steady state there are important differences.

3.3 Convergence

According to a suggestion of Burmeister en Dobell (1970), following Solow (1956), the effective labour force may not only depend on time, but also on real wages:

$$N = A{*}POP{*}\psi(w)$$

The function $\psi(w)$ denotes the participation rate, which depends on the real wage rate (w). In this case the accumulation equation (3.6) is supplemented with an additonal term:

$$\frac{dk}{dt} = \sigma k^{\alpha} - gk - \eta_{\psi}\eta_{w}\frac{dk}{dt}, \text{ where } \eta_{\psi}>0 \text{ and } \eta_{w}>0 \qquad (3.9)$$

Here η_{ψ} is the elasticity of the participation rate with respect to the wage rate and η_{w} the elasticity of the wage rate with respect to the capital-intensity. When $d\psi/dw>0$ as we normally would expect (and since dw/dk is always positive), the qualitative behaviour of the capital-intensity is unaltered by this modification, allowing the stability conclusions of the standard Solow model to remain valid. The steady state is again described by (3.7). This implies that countries are in the same steady state, although they may exhibit different participation rates. Outside the steady state however the international variation in participation rates may have important consequences. The following examples serve to illustrate this.

First assume two countries which at time $t=0$ are completely identical (the same Y, K, P, POP, A, α, σ en g). In terms of figure 1, both countries are at the left of the steady-state capital-intensity. In addition, assume that the participation rate is <u>endogenous</u> in country 1 and <u>exogenous</u> in country 2. Convergence to the steady state implies rising real wages. This induces a growing labour supply in country 1, so that growth in this country lags behind that of country 2. During the adjustment process labour productivity of country 2, with the fixed participation rate, instantly surpasses labour productivity of country 1, where the participation rate is rising. Consequently country 2 will approach the steady state faster than country 1. (We abstract from international mobility of labour, which speeds up convergence between countries; Barro and Sala-i-Martin, 1990.) In the steady state both countries have the same capital-intensity again. There is a difference however. The labour force (L) and consequently output (Y), consumption (C) and the stock of capital (K), are greater in country 1 than in country 2. In other words, the steady-state level of output in a country with more working hours is higher than that in an otherwise completely identical country with more leisure.

It may be helpful to demonstrate the effects of different participation rates with the aid of a numerical example, without an endogenous labour supply. Assume two identical countries with exogenous participation rates, where $POP=A=1$, $K(0)=2$, $\alpha=0.5$, $\sigma=0.3$, $\pi=\rho=0$ en $\delta=0.1$. The only difference is that $P=1$ in country 1 while $P=0.5$ in country 2. Table 3 describes the initial positions and the dynamics of convergence to the steady state.

Table 3

Both countries start with the same capital stock, K(0). That is why country 1 with the high participation rate exhibits a lower capital-intensity than country 2. (Notice that in terms of income per capita (Y/POP) the differences are the other way about.) For both countries the steady state is reached at $y^*=3$ and $k^*=9$. At any moment in time, country 1 is farther away from the steady state than country 2. This difference persists, although it diminishes in course of time. Thus country 1 grows faster than country 2. This is the well-known neoclassical convergence prediction. Identical countries with different initial positions will converge to the same steady state. In the recent past there is a renewed interest for this prediction (Baumol, 1986, Baumol en Wolff, 1988, DeLong, 1988, Barro en Sala-i-Martin, 1990, 1991 en Barro, 1991). However, the possibility that such countries (with the same σ and g) may exhibit important differences in income per capita (Y/POP), which can be traced back to different participation rates, has received little attention in the literature.

The examples show that the negative relationship between productivity and participation essentially is another manifestation of the negative relation between growth and the level of productivity at some initial date as predicted by the Solow model. Countries with low participation rates are relatively close in the neighbourhood of their steady state and consequently exhibit lower growth rates than countries with high participation rates.

3.4 First results

The Solow model does not predict convergence to the same steady-growth path if population growth and savings rates differ between countries. In that case the model predicts conditional convergence, in which each country converges to its own steady state. Thus, apart from the effect on growth rates of different productivity levels at some initial date, convergence takes place at country-specific growth rates.

Let Y/L be the actual value of productivity and let $(Y/L)^*$ be the steady-state value of productivity, then linearizing around the steady state results in (Mankiw, et.al., 1990):

$$\frac{d\ell n \frac{Y}{L}}{dt} = \lambda[\ell n(\tfrac{Y}{L})^* - \ell n \tfrac{Y}{L}], \text{ where } \lambda = g(1-\alpha) \tag{3.10}$$

The convergence rate is λ. If for instance g=0.10 and α=1/2 then λ=0.05, hence the economy moves halfway to the steady state in about 14 years. Equation (3.10) implies:

$$\Delta\ell n\tfrac{Y}{L} = \ell n\tfrac{Y}{L} - \ell n\tfrac{Y}{L}(0) = (1-e^{-\lambda t})[\ell n(\tfrac{Y}{L})^* - \ell n\tfrac{Y}{L}(0)] \tag{3.11}$$

Thus growth is a function of the initial level of productivity and the steady-state level of productivity, the latter serving as an <u>attractor</u> to which economic growth ultimately converges. Equation (3.11) expresses the negative relationship between growth and the level of productivity at an initial date. A well-known criticism of this prediction is that it only holds for the richest countries (DeLong, 1988). For a more extended sample this relation clearly does not hold[5]. From a theoretical point of view however this criticism is not justified, because this partial relation cannot be decoupled from the determinants of the ultimate steady state.

In (3.11), the steady state can be made explicit by substituting (3.8) into it. Assuming $\ell nA(0) = a + \varepsilon$ and t=0 the result is:

$$\ell n\frac{Y}{L} = (1-e^{-\lambda t})[\frac{\alpha}{1-\alpha}(\ell n\sigma - \ell ng) + a] + e^{-\lambda t}\ell n\frac{Y}{L}(0) \qquad (3.12)$$

This equation describes the <u>level</u> of productivity at some moment in time. Assuming that σ en g are independent of ε, it is allowed to estimate this equation with OLS.

As equation (3.12) embodies the convergence dynamics, it is preferred to (3.8). This advantage is important, because there is no adequate empirical information on steady-state productivity levels. Thus with equation (3.12) we restrict ourselves to the explanation of the international variation in productivity in a certain year, where σ and g function as a measure for the country-specific steady state to which productivity converges.

Equation (3.12) does not contain the participation rate. As we have seen above, the international variation in labour force participation is connected with the international variation of productivity at some initial date. In case of constant participation rates, (3.12) would suffice. In reality however labour force participation has strongly changed. In the rich and sub-rich countries the participation rates have increased, whereas in the poor and poorest countries participation has diminished (see table 2). For these countries this points at a slower respectively faster convergence to the steady state than in the group of countries (III, see table 2) where the participation rates approximately have remained unchanged. This is treated by adding the change of the participation rate to equation (3.12).

The effect of this addition will be recognized by estimating the Solow model first without participation.

The dependent variable is GDP per worker in 1988. The explanatory variables are the rate of investment σ_k averaged over 1960-1988 as an appromixation for the steady-state savings rate and the average growth rate of total population. Notice that in this period economic growth has slowed down, especially in the richest countries[6]. However, for the Solow model it is not necessary to model this slowdown, because in approaching the steady state convergence will go slower. In this respect the Solow model is consistent with the high growth rates in the sixties and the slowdown afterwards. Estimating (3.12) without imposing restrictions on the coefficients gives:

$$\ell n\frac{Y}{L}(88) = \underset{(4.29)}{0.35}\,\ell n\sigma_k - \underset{(-1.80)}{0.68}\,\ell ng + \underset{(14.95)}{0.87}\,\ell n\frac{Y}{L}(60) + \underset{(1.80)}{1.92} \tag{3.13}$$

$$\bar{R}^2 = 0.88,\ N = 95 \text{ en } SSE = 13.49$$

The numbers between brackets are t-values, whereas SSE is the residual sum of squares. All coefficients have the expected sign. The explained variance is substantial. The equation describes nearly 90% of the international variation in productivity in 1988.

Equation (3.13) also has a defect, however. It appears that the t-value of the coefficient of the growth rate is low, as compared with the t-value of the coefficient of the rate of investment. Presumably population growth as a determinant of country-specific steady growth does not show up well. This is connected with the already observed difference between population growth and growth of the labour force (see table 2). Mankiw et al. (1990) have used the growth rate of the working-age population, so that changes in the participation rate affect their results. However, it is more accurate to make this explicit, so that population growth as a determinant of the steady state can show up better. This can be captured by adding the change of the participation rate from 1960 to 1988 to the equation. However, from equation (2.3) we already know that the relation between productivity and participation in 1988 is completely absent. This has to do with the fact that the convergence to the steady state, which is approximated by the investment rates and population growth of the period preceding 1988, will be completed to an considerable extent in this year. In 1988 countries are closer to the steady state than in 1960, so that the international variation in participation rates in 1988 carries less weight for the convergence dynamics than that of 1960. The latter is affirmed by equation (2.2) above. It therefore suffices to introduce the participation rate of 1960 only:

$$\ell n\frac{Y}{L}(88) = \underset{(4.41)}{0.35}\ \ell n\sigma_k - \underset{(-2.73)}{1.09}\ \ell ng - \underset{(-2.56)}{0.52}\ \ell nP(60) + \underset{(11.89)}{0.78}\ \ell n\frac{Y}{L}(60) + \underset{(3.16)}{5.37} \qquad (3.14)$$

$$\bar{R}^2 = 0.88,\ N = 95 \text{ en } SSE = 12.57$$

In this equation population growth clearly matters. The negative relation between productivity in 1988 and participation in 1960 shows up well[7]. However, theory requires that the coefficients of the rate of investment and population growth are restricted to be equal to each other with an opposite sign[8]:

$$\ell n\frac{Y}{L}(88) = \underset{(5.16)}{0.40}\ (\ell n\sigma_k - \ell ng) - \underset{(-2.02)}{0.38}\ \ell nP(60) + \underset{(14.83)}{0.84}\ \ell n\frac{Y}{L}(60) + \underset{(2.99)}{2.89} \qquad (3.15)$$

$$\bar{R}^2 = 0.88,\ N = 95 \text{ en } SSE = 13.01$$

Compared with (3.14) the residual sum of squares hardly has increased, so that the restriction need not be rejected (F-test on the restriction yields $F=3.117$). The negative relation between productivity and participation needs to be rejected neither.

A less good point of equation (3.15) is the value of the production-elasticity of capital ($\alpha=0.72$). This is clearly to high, as compared with the empirical value of the capital share in income of about 1/3. The estimated value of α is even closer in the neighbourhood of 1 than 1/3. Thus we cannot rule out the possibility that $\alpha=1$. In this case there are no longer decreasing returns to the set of reproducible inputs, which is the central presupposition of the Solow model. (In case $\alpha=1$ the Solow model is transformed into an endogenous growth model.) Further it appears that the speed of convergence is very low ($\lambda=0.006$), implying that the economy moves halfway to the steady state in about 116 years. The high value of α leads to the conclusion that the standard Solow model cannot be accepted.

4. The adapted Solow model

4.1 A preliminary example

The Ramsey version of neoclassical growth theory stresses the intertemporal trade-off between consumption and leisure. In this model both the savings rate and the participation rate may be endogenous, depending on parameters such as the rate of time preference and the probability of dying (Blanchard en Fisher, 1989). The measurement of these parameters is an important problem in the empirical implementation of such models. Inspired by the work of for instance Barro, several proxies have been constructed. The introduction of such variables might improve the Solow model to a considerable extent. To illustrate this, let us add the average age of the labour force (AV) to equation (3.12) as an (arbitrary) example:

$$\ell n\frac{Y}{L}(88) = \underset{(3.40)}{0.27}(\ell n\sigma_k - \ell ng) \; \underset{(-3.21)}{-0.61}\ell nP(60) \; \underset{(9.12)}{+0.67}\ell n\frac{Y}{L}(60) + \underset{(3.48)}{3.66}\ell nAV(60) \; \underset{(-2.42)}{-7.68} \quad (4.1)$$

$$\bar{R}^2 = 0.89, \; N = 95 \text{ en } SSE = 11.46$$

AV(1960) has been taken from the dataset of Barro (1991). The average age of the labour force is positively correlated to productivity. Comparing this result with (3.15) it appears that adding AV has changed the values of the coefficients to a considerable extent (α=0.45 in stead of α=0.72 and λ=0.0143 in stead of λ=0.006). The value of α even becomes more plausible if the poorest countries are left aside (N=76: α=0.375).

Equation (4.1) indicates that the Solow model, provided that it is augmented appropriately, is well able to describe the international variation in productivity in a satisfactory way. Recently Mankiw et al. (1990) have already reached this conclusion. They stick to the standard Solow model with exogenous savings, only by adding human capital. It will be shown that this is a fruitful point of view to shed more light on the negative relation between productivity and participation.

4.2 Human capital

The introduction of human capital (H) changes equation (3.1) into:

$$Y = K^{\alpha}H^{\beta}N^{1-\alpha-\beta}, \text{ met } \alpha+\beta<1 \tag{4.2}$$

The condition $\alpha+\beta<1$ implies decreasing returns to reproducible inputs, so that the neoclassical basic assumption is preserved. Written in effective units of labour the production function reads:

$$y = k^{\alpha}h^{\beta}, \text{ waarin } y = Y/N, \; k = K/N \text{ en } h = H/N \tag{4.3}$$

In order to minimize the differences with the standard model it is assumed that consumption can be transformed costlessly into physical or human capital and that human capital depreciates at the same rate as physical capital does. The consumption function again is $c=(1-\sigma)y$, but now $\sigma=\sigma_k+\sigma_h$. In this case the dynamics of the economy is governed by two accumulation equations:

$$\frac{dk}{dt} = \sigma_k y - gk \text{ en } \frac{dh}{dt} = \sigma_h y - gh \tag{4.4}$$

This model predicts a <u>fixed</u> ratio between human and physical capital in the steady state, which equals the ratios of the savings rates. Using this ratio, the steady-state levels are easily found as:

$$k^{*} = [(\sigma_k^{1-\beta}\;\sigma_h^{\beta})/g]^{1/(1-\alpha-\beta)} \tag{4.5}$$

and

$$h^{*} = [(\sigma_h^{1-\alpha}\;\sigma_k^{\alpha})/g]^{1/(1-\alpha-\beta)} \tag{4.6}$$

Substituting (4.5) and (4.6) into (4.3), taking logs and rearranging terms results in an equation which is similar to (3.8).

$$\ln\frac{Y}{L} = \ln A(0) + \rho t + \frac{\alpha}{1-\alpha-\beta}\ln\sigma_k + \frac{\beta}{1-\alpha-\beta}\ln\sigma_h - \frac{\alpha+\beta}{1-\alpha-\beta}\ln g \tag{4.7}$$

If for instance $\alpha=\beta=1/3$, the coefficient of $\ln\sigma_k$ equals 1. According to (3.8) the elasticity is 0.5. Hence, the presence of human-capital accumulation increases the impact of physical-capital accumulation on productivity.

4.3 Final results

Substituting equation (4.7) into (3.11) gives an equation similar to (3.12):

$$\ln\frac{Y}{L} = (1-e^{-\lambda t})\left[\frac{\alpha}{1-\alpha-\beta}\ln\sigma_k + \frac{\beta}{1-\alpha-\beta}\ln\sigma_h - \frac{\alpha+\beta}{1-\alpha-\beta}\ln g + a\right] + e^{-\lambda t}\ln\frac{Y}{L}(0) \qquad (4.8)$$

with speed of convergence:

$$\lambda = g(1-\alpha-\beta)$$

If for instance $g=0.06$ and $\alpha=\beta=1/3$, then $\lambda=0.02$, so that the economy moves halfway to the steady state in about 35 years.

In estimating equation (4.8) the measurement of human capital is a practical problem. The average degree of schooling of the labour force could be a good measure for σ_h, but for the broad spectrum of countries considered here this measure is not available. That is why we propose to approximate investment in human capital by[9]:

$$\sigma_h = \frac{\text{Students}}{\text{POP(12-17)}}\,\frac{\text{POP}}{\text{L}} = \frac{\text{SER}}{\text{P}} = \frac{\text{Students/L}}{\text{POP(12-17)/POP}}$$

POP is total population, L the labour force, P the participation rate and SER de Secondary Enrollment Rate, that is the number of students in secondary school as a percentage of population in the same age.

The third way of writing shows that investment in human capital increases as the ratio between students and the labour force raises and/or as the share of young people in total population diminishes. According to the second way of writing the same happens if the degree of schooling of young people increases and/or the participation rate decreases. These ratios should be considered as representative for steady-state investment in human capital. This raises the problem that, up till now, secondary enrollment rates have increased instantly. That is why we take for SER the most recent data available, namely for the year 1985 (Barro, 1991). The participation rate again is from 1960. This is motivated by the reasoning that - given the same degree of schooling of young people - the degree of schooling of the labour force in a country with a low participation rate is higher than in a country with a high participation rate.

The data in table 2 show a positive correlation between productivity and investment in human capital. Nevertheless, the variation of σ_h even within the group of rich countries is considerable. A ranking of the first 10 countries in terms of σ_h shows the Netherlands at top, followed by South Korea, Canada, Belgium, Norway, the USA, Ireland, Spain, Australia and New Zealand. The favourable position of the Netherlands and South Korea depends on the relatively low participation rates in these countries. In contrast Switzerland for instance has a very low rate of investment in human capital, because in this country a low degree of schooling is coupled to a high participation rate.

Without imposing restrictions, estimation of (4.8) gives:

$$\ell n\frac{Y}{L}(88) = \underset{(3.51)}{0.27}\ \ell n\sigma_k - \underset{(-2.16)}{0.72}\ \ell ng + \underset{(4.97)}{0.28}\ \ell n\sigma_h + \underset{(9.97)}{0.66}\ \ell n\frac{Y}{L}(60) + \underset{(3.38)}{3.36} \qquad (4.9)$$

$$\bar{R}^2 = 0.90,\ N = 95 \text{ en } SSE = 10.59$$

And after imposing restrictions, we get:

$$\ell n\frac{Y}{L}(88) = \underset{(3.86)}{0.27}\ (\ell n\sigma_k - \ell ng) + \underset{(5.05)}{0.28}\ (\ell n\sigma_h - \ell ng) + \underset{(10.52)}{0.67}\ \ell n\frac{Y}{L}(60) + \underset{(5.76)}{2.93} \qquad (4.10)$$

$$\bar{R}^2 = 0.90,\ N = 95 \text{ en } SSE = 10.62$$

The restriction that the coefficients of $\ell n\sigma_k$, $\ell n\sigma_h$ and ℓng sum to zero, is not rejected (F=0.12). From a theoretical view point equation (4.10) is acceptable, as appears from the value of α, which is in the neighbourhood of the expected value of 1/3 (α=0.31, whereas β=0.32)[10]. The value of the speed of convergence (λ=0.0142) implies that the economy moves halfway to the steady state in about 50 years[11]. This is less than half of the time, predicted by the Solow model according to (3.15). Nevertheless the period of adjustment is very long. However, recursive regression shows that this is mainly due to the influence of the poor countries in the sample. Restricting the number of countries for instance to the 70 richest countries at date 1985 gives $\lambda=0.0219$. In this case the economy moves halfway in about 32 years[12]. Further research must show whether this can be traced back to factors specific for poor countries. Investigations of for instance Kormendi en Meguire (1985), Grier and Tullock (1989) and Barro (1991) give ground for this direction of reserach.

5. Conclusion

Just like the standard Solow model, the model with human capital predicts conditional convergence. Countries will approach the steady state, determined by the country-specific investment rates and population growth. These positions can now be calculated by substituting $\alpha=\beta=1/3$ and the country-specific values of σ_k, σ_h and g into the equations (4.3), (4.5) and (4.6). The results show the steady-state position of each country on the (world)production function. It appears that the ranking of countries in terms of their steady-state output-intensity strongly diverges from the ranking in table 2 on the basis of actual labour productivity in 1985. The first 5 countries now are Finland, Norway, Denmark, Belgium and the Netherlands. These countries have in common that population growth is relatively low. Moreover these countries show high investment rates in human capital. In addition the Scandinavian countries exhibit high rates of investment in physical capital, which altogether explains their leading position on the production function.

Our results thus show a remarkable picture of the country-specific steady-state positions in the world. Nevertheless the position of the poor countries remains to be very low. According to the Solow model adjusted with human capital, this can be changed if the investment rates increase and population growth weakens in these countries. In this respect, investment in human capital, by higher degrees of schooling and/or lower participation rates, may serve as an engine of growth by inducing more investment in physical capital and eventually lower birth rates.

Table 1 The data of Maddison

GDP per hour, 1900-1986 (US=100)

	1900	1913	1950	1973	1986
1 AUSTRALIA	94 (2)	86 (2)	64 (3)	68 (6)	73 (11)
2 AUSTRIA	47 (10)	46 (10)	26 (15)	57 (14)	70 (13)
3 BELGIUM	63 (5)	58 (6)	40 (10)	62 (12)	90 (2)
4 CANADA	61 (6)	76 (3)	76 (2)	85 (2)	89 (3)
5 DENMARK	52 (8)	56 (7)	42 (9)	61 (13)	63 (15)
6 FINLAND	30 (15)	31 (15)	30 (13)	55 (15)	65 (14)
7 FRANCE	41 (12)	41 (14)	38 (11)	67 (7)	89 (4)
8 GERMANY	49 (9)	48 (9)	29 (14)	63 (11)	79 (7)
9 ITALY	39 (14)	42 (11)	33 (12)	66 (8)	74 (10)
10 JAPAN	16 (16)	17 (16)	13 (16)	40 (16)	51 (16)
11 NETHERLANDS	73 (4)	67 (5)	51 (6)	78 (3)	84 (5)
12 NORWAY	39 (13)	42 (12)	42 (8)	64 (10)	84 (6)
13 SWEDEN	42 (11)	41 (13)	46 (7)	70 (4)	75 (8)
14 SWITZERLAND	53 (7)	53 (8)	58 (4)	70 (5)	73 (12)
15 UK	81 (3)	74 (4)	54 (5)	64 (9)	75 (9)
16 USA	100 (1)	100 (1)	100 (1)	100 (1)	100 (1)

Participation rates 1900-1986

	1900	1913	1950	1973	1986
1 AUSTRALIA	39.5	41.6	42.3	43.2	43.9
2 AUSTRIA	44.8	46.1	46.4	41.7	42.6
3 BELGIUM	42.3	44.0	38.7	39.3	37.9
4 CANADA	37.5	38.4	36.6	40.1	45.8
5 DENMARK	42.2	42.8	46.3	48.3	52.0
6 FINLAND	43.8	43.7	48.9	47.0	50.0
7 FRANCE	49.7	50.4	45.6	40.6	38.4
8 GERMANY	40.5	42.4	42.3	43.3	42.1
9 ITALY	44.8	45.2	39.6	41.7	43.5
10 JAPAN	55.0	49.8	42.7	48.4	48.2
11 NETHERLANDS	37.2	37.8	35.8	35.6	36.6
12 NORWAY	39.3	40.2	43.7	41.8	50.0
13 SWEDEN	45.1	46.1	48.6	47.7	51.0
14 SWITZERLAND	48.7	49.3	47.7	50.9	49.0
15 UK	42.9	43.6	44.5	44.6	43.2
16 USA	36.6	39.8	40.5	41.9	46.1

Source: A. Maddison, The World Economy in the 20th Century, Paris, 1989. Here the participation rate is defined as the ratio between employment (= labour force minus unemployment) and population.

Table 2 Summary of the data of Summers en Heston (95 countries)

Group	Rank	G	π	GL	GL-π	σ_k	σ_h	P(60)	CU60	CU88
I	1-19	2.6	0.87	1.33	0.46	26.2	21.5	41.7	56.9	71.6
II	20-38	2.3	1.96	2.19	0.23	20.5	17.1	34.4	30.2	36.3
III	39-57	2.6	2.54	2.50	-0.04	16.5	14.1	35.9	15.2	18.8
IV	58-76	0.9	2.84	2.36	-0.48	12.6	5.5	46.2	9.5	8.0
V	77-95	0.8	2.56	2.06	-0.50	10.7	3.1	50.4	4.9	3.6
All countries		1.8	2.15	2.09	-0.06	17.3	12.3	41.7	23.4	27.7

Average values of the growth rate of labour productivity (G), the growth rate of population (π), the growth rate of the labour force (GL), the investment rate in physical capital (σ_k), the investment rate in human capital (σ_h), the participation rate 1960 (P60) and the productivity level as a percentage of US-productivity in 1960 and 1988 (CU60 en CU88).

Table 3 Numerical example of convergence to the steady state

	Country 1 (P=1, so that L=1)						Country 2 (P=0.5, so that L=0.5)					
t	y	k	dk/dt	Y	K	C	y	k	dk/dt	Y	K	C
0	1.41	2.00		1.41	2.00	0.99	2.00	4.00		1.00	2.00	0.70
1	1.49	2.22	11.2	1.49	2.22	1.04	2.05	4.20	5.0	1.03	2.10	0.72
2	1.57	2.45	10.1	1.57	2.45	1.10	2.10	4.39	4.6	1.05	2.20	0.73
14	2.22	4.92	3.8	2.22	4.92	1.55	2.51	6.30	2.1	1.25	3.15	0.88
100	2.99	8.94	0.0	2.99	8.94	2.09	2.99	8.96	0.0	1.50	4.48	1.05
∞	3	9	0	3	9	2.1	3	9	0	1.50	4.50	1.05

For both countries: A=POP=1, α=0.5, σ=0.3, π=ρ=0 and δ=0.1.

Footnotes

1. A combined cross-section-time-series analysis with the data of Maddison (1989) leads to:

$$\ell n(Y/L) = \underset{(-3.84)}{-1.61\ell nP} + \underset{(21.47)}{1.21\ell n(Y/L)(USA)} + \underset{(2.24)}{3.63} \qquad \bar{R}^2=0.85$$

The numbers between brackets are t-values. The number of observations is 80, namely 16 countries for the years 1900, 1913, 1950, 1973 and 1986. The dependent variable is GDP per working hour, which is explained by the participation rate (P) and the US-productivity level. The latter term expresses the catching-up phenomenon (Abramovitz (1989), Dowrick and Nguyen (1989) and Scott (1989).

2. The ranking in 1985 is:

1 USA 2 CANADA 3 SWITZERLAND 4 NORWAY 5 NETHERLANDS 6 AUSTRALIA 7 ITALY 8 FRANCE 9 BELGIUM 10 ISRAEL 11 SWEDEN 12 GERMANY 13 NEW ZEALAND 14 AUSTRIA 15 FINLAND 16 UK 17 DENMARK 18 JAPAN 19 SINGAPORE 20 TRIN&TOB 21 HONG KONG 22 SPAIN 23 VENEZUELA 24 MEXICO 25 IRELAND 26 GREECE 27 ALGERIA 28 SOUTH AFRICA 29 MALAYSIA 30 URUGUAY 31 ARGENTINA 32 BRAZIL 33 CHILE 34 PANAMA 35 COLOMBIA 36 TUNISIA 37 PORTUGAL 38 COSTA RICA 39 MAURITIUS 40 KOREA, SOUTH 41 ECUADOR 42 PERU 43 GUATEMALA 44 TURKEY 45 DOM. REP 46 BOTSWANA 47 EGYPT 48 PARAGUAY 49 CONGO 50 MOROCCO 51 NICARAGUA 52 SRI LANKA 53 JAMAICA 54 BOLIVIA 55 PHILIPPINES 56 THAILAND 57 PAKISTAN 58 EL SALVADOR 59 CAMEROON 60 INDONESIA 61 HONDURAS 62 IVORY COAST 63 ZIMBABWE 64 PA N. GUINEA 65 SUDAN 66 NIGERIA 67 MAURITANIA 68 SIERRA LEONE 69 SENEGAL 70 LIBERIA 71 BANGLADESH 72 BENIN 73 ZAMBIA 74 SOMALIA 75 GHANA 76 KENYA 77 ANGOLA 78 INDIA 79 NEPAL 80 TOGO 81 MADAGASCAR 82 MOZAMBIQUE 83 BURMA 84 CHAD 85 RWANDA 86 CEN AFRICA 87 MALAWAI 88 MALI 89 NIGER 90 BURKINA FASO 91 BURUNDI 92 TANZANIA 93 ZAIRE 94 UGANDA 95 ETHIOPIA

3. See for instance Burmeister (1980).

4. Here the participation rate is the ratio between the labour force (L) and total population (POP) and not the ratio between working-age population and total population as is implicit in Mankiw, et.al. (1990).

5. The following regression with the data of Summers en Heston shows this (N=95):

$$\ln(Y/L)(88) - \ln(Y/L)(60) = \underset{(1.15)}{0.05} \ln(Y/L)(60) + \underset{(0.16)}{0.06} \qquad \bar{R}^2=0.003$$

6. See for instance Scott (1989).

7. This equation can be decomposed as follows:

$$\ln(Y/L)(88) = -\ 5.16\ \ln ng + 18.85 \qquad \bar{R}^2=0.41$$
$$\ln(Y/L)(88) = -\ 5.27\ \ln ng - 2.12\ \ln P(60) + 26.89 \qquad \bar{R}^2=0.60$$
$$\ln(Y/L)(88) = -\ 3.98\ \ln ng - 1.76\ \ln P(60) + 0.68\ \ln\sigma_k + 21.20 \qquad \bar{R}^2=0.70$$

8. Estimation of this equation in the form of (3.11) gives:

$$\Delta\ln(Y/L) = \underset{(5.16)}{0.40} (\ln\sigma_k - \ln ng) - \underset{(-2.02)}{0.38} \ln P(60) - \underset{(-2.73)}{0.16} \ln(Y/L)(60) + \underset{(2.99)}{2.89} \qquad \bar{R}^2=0.22$$

The values of the coefficients are not altered. The only difference with (3.15) is the much lower t-value of the productivity level in 1960 and consequently the reduction of explained variance.

9. Mankiw, et.al. (1990) introduce the following approximation:

$$\sigma_h(MRW) = SER \frac{POP(15\text{-}19)}{POP(15\text{-}65)}$$

We prefer the approximation of the investment rate in human capital as given in the text. Evidently both approximations are strongly correlated:

$$\ln\sigma_h = \underset{(32.85)}{1.07} \ln\sigma_h(MRW) + \underset{(12.78)}{0.68} \qquad \bar{R}^2=0.92$$

10. In the form of (3.11):

$$\Delta \ell n\frac{Y}{L} = \underset{(3.86)}{0.27} (\ell n\sigma_k - \ell ng) + \underset{(5.05)}{0.28} (\ell n\sigma_h - \ell ng) - \underset{(-5.12)}{0.33} \ell n\frac{Y}{L}(60) + \underset{(5.76)}{2.93}$$

$\bar{R}^2 = 0.37$, $N = 95$ en $SSE = 10.62$

11. This result is better than that of Mankiw, et.al. (1990), who find α=0.48, which is clearly too high.

12. The equation is (N=70):

$$\Delta \ell n\frac{Y}{L} = \underset{(3.58)}{0.27} (\ell n\sigma_k - \ell ng) + \underset{(4.32)}{0.35} (\ell n\sigma_h - \ell ng) - \underset{(-6.54)}{0.46} \ell n\frac{Y}{L}(60) + \underset{(7.21)}{4.09}$$

$\bar{R}^2 = 0.44$ en $N = 70$

This gives α=0.25, β=0.32 and λ=0.0219.

References

Barro R.J. (1991): "Economic Growth in a Cross Section of Countries", The Quarterly Journal of Economics, 106, 407-443.

Barro R.J, Sala-i-Martin X. (1990): "Economic Growth and Convergence across the United States", NBER Working Paper, No. 3419.

Barro R.J, Sala-i-Martin X. (1991): "Convergence across States and Regions", Brookings Papers on Economic Activity, 1:1991, 107-182.

Baumol W.J. (1986): "Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show", The American Economic Review, 76, 1072-1085.

Baumol W.J., Wolff E.N. (1988): "Productivity Growth, Convergence, and Welfare: Reply", The American Economic Review, 78, 1155-1159.

Bhasin V.K. (1991): "Variable Labor Force Growth and Neoclassical Models of Growth", Journal of Macroeconomics, 13, 351-379.

Blanchard O.J, Fischer S. (1989): Lectures on Macroeconomics, MIT Press, Cambridge, Massachusetts.

Boggess T.E. (1983): "A Generalized Keynes-Wicksell Model with Variable Labor Force Growth", Journal of Macroeconomics, 5, 197-209.

Burmeister E., Dobell A.R. (1970): Mathematical Theories of Economic Growth, Macmillan, London.

Burmeister E. (1980): Capital Theory and Dynamics, Cambridge University Press, Cambrdige.

Davis E. (1969): "A Modified Golden Rule: The Case with Endogenous Labor Supply", The American Economic Review, 59, 177-181.

DeLong J.B. (1988): "Productivity Growth, Convergence, and Welfare: Comment", The American Economic Review, 78, 1138-1154.

Dowrick S., Nguyen D-T. (1989): "OECD Comparative Economic Growth 1950-85: Catch-Up and Convergence", The American Economic Review, 79, 1010-1030.

Grier K.B., Tullock G. (1989): "An Empirical Analysis of Cross-National Economic Growth, 1951-80", Journal of Monetary Economics, 24, 259-276.

Kormendi R.C., Meguire P.G. (1985): "Macroeconomic Determinants of Growth: Cross-Country Evidence", Journal of Monetary Economics, 16, 141-163.

Maddison A. (1982): Phases of Capitalist Development, Oxford University Press, Oxford.

Maddison A. (1989): The World Economy in the 20th Century, OECD, Paris.

Mankiw N.G., Romer D., Weil D.N. (1990): "A Contribution tot the Empirics of Economic Growth", NBER Working Paper, No. 3541. (Forthcoming in The Quarterly Journal of Economics).

Scott M.F. (1989): A New View of Economic Growth, Oxford University Press, Oxford.

Solow R.M. (1956): "Model of Growth", The Quarterly Journal of Economics, 70, 65-94.

Summers R., Heston A. (1991): "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988", The Quarterly Journal of Economics, 106, 327-368.

Appendix The data

Countries in the dataset of Summers/Heston (1991) and Barro (1991). The sample is 1960-1988, unless otherwise stated.

		S/H	BAR	SAMP
1	USA	66	98	88
2	CANADA	50	86	88
3	SWITZERLAND	127	82	88
4	NORWAY	122	78	88
5	NETHERLANDS	121	77	88
6	AUSTRALIA	131	111	88
7	ITALY	118	74	88
8	FRANCE	112	69	88
9	BELGIUM	108	65	88
10	ISRAEL	89	49	88
11	SWEDEN	126	81	88
12	GERMANY	113	70	88
13	NEW ZEALAND	133	113	88
14	AUSTRIA	107	64	88
15	FINLAND	111	68	88
16	UK	129	84	88
17	DENMARK	110	67	88
18	JAPAN	90	50	88
19	SINGAPORE	188	59	85
20	TRIN&TOB	65	97	88
21	HONG KONG	84	45	88
22	SPAIN	125	80	88
23	VENEZUELA	78	110	87
24	MEXICO	60	94	88
25	IRELAND	117	73	88
26	GREECE	114	71	88
27	ALGERIA	1	1	88
28	SOUTH AFRICA	38	33	88

29 MALAYSIA	94	54	88
30 URUGUAY	77	109	88
31 ARGENTINA	67	99	88
32 BRAZIL	69	101	**87**
33 CHILE	70	102	88
34 PANAMA	62	96	**86**
35 COLOMBIA	71	103	88
36 TUNISIA	43	38	88
37 PORTUGAL	124	79	88
38 COSTA RICA	51	87	88
39 MAURITIUS	28	24	88
40 KOREA, SOUTH	92	52	88
41 ECUADOR	72	104	88
42 PERU	75	107	88
43 GUATEMALA	56	90	88
44 TURKEY	128	83	88
45 DOM. REP	53	88	88
46 BOTSWANA	4	4	**86**
47 EGYPT	13	10	88
48 PARAGUAY	74	106	88
49 CONGO	12	9	**86**
50 MOROCCO	29	25	88
51 NICARAGUA	61	95	**86**
52 SRI LANKA	101	60	**87**
53 JAMAICA	59	93	**87**
54 BOLIVIA	68	188	88
55 PHILIPPINES	98	57	88
56 THAILAND	104	63	88
57 PAKISTAN	97	56	88
58 EL SALVADOR	54	89	88
59 CAMEROON	7	6	88
60 INDONESIA	86	118	**62**/88
61 HONDURAS	58	92	88
62 IVORY COAST	20	16	88
63 ZIMBABWE	47	42	88
64 PA N. GUINEA	134	114	88

65 SUDAN	39	34	88
66 NIGERIA	32	28	88
67 MAURITANIA	27	23	88
68 SIERRA LEONE	36	31	87
69 SENEGAL	34	30	88
70 LIBERIA	23	19	86
71 BANGLADESH	81	43	85
72 BENIN	3	3	88
73 ZAMBIA	46	41	88
74 SOMALIA	37	32	88
75 GHANA	17	14	88
76 KENYA	21	17	88
77 ANGOLA	2	2	85
78 INDIA	85	46	88
79 NEPAL	95	55	85
80 TOGO	42	37	88
81 MADAGASCAR	24	20	88
82 MOZAMBIQUE	30	26	88
83 BURMA	82	44	85
84 CHAD	10	8	85
85 RWANDA	33	29	88
86 CEN AFRICA	9	7	88
87 MALAWAI	25	21	88
88 MALI	26	22	88
89 NIGER	31	27	88
90 BURKINA FASO	5	115	65/88
91 BURUNDI	6	5	88
92 TANZANIA	41	36	88
93 ZAIRE	45	40	88
94 UGANDA	44	39	85
95 ETHIOPIA	14	11	86

	G	π	GL	GL-π
1 USA	1.52	1.10	1.77	.67
2 CANADA	1.59	1.35	2.43	1.08
3 SWITZERLAND	1.82	.71	.87	.15
4 NORWAY	2.80	.57	1.42	.85
5 NETHERLANDS	2.08	.89	1.41	.51
6 AUSTRALIA	1.70	1.70	2.22	.51
7 ITALY	3.68	.48	.38	-.09
8 FRANCE	2.84	.72	.86	.13
9 BELGIUM	2.56	.28	.57	.29
10 ISRAEL	2.85	2.68	2.97	.28
11 SWEDEN	1.93	.39	.96	.57
12 GERMANY	2.59	.34	.40	.06
13 NEW ZEALAND	.38	1.21	1.95	.73
14 AUSTRIA	3.42	.25	.16	-.08
15 FINLAND	3.08	.39	.79	.40
16 UK	2.11	.29	.45	.16
17 DENMARK	1.91	.40	1.07	.67
18 JAPAN	5.34	.94	1.12	.18
19 SINGAPORE	4.44	1.77	3.33	1.56
20 TRIN&TOB	.39	1.69	1.92	.23
21 HONG KONG	5.25	2.24	3.37	1.13
22 SPAIN	3.83	.88	.72	-.16
23 VENEZUELA	1.15	3.45	3.73	.28
24 MEXICO	1.38	2.83	3.45	.62
25 IRELAND	2.33	.83	.89	.05
26 GREECE	4.36	.66	.43	-.23
27 ALGERIA	2.30	2.86	2.30	-.55
28 SOUTH AFRICA	1.47	2.28	2.22	-.05
29 MALAYSIA	3.04	2.62	3.11	.49
30 URUGUAY	.63	.60	.54	-.06
31 ARGENTINA	.96	1.52	1.18	-.34
32 BRAZIL	3.86	2.50	2.99	.49
33 CHILE	.66	1.82	2.15	.33
34 PANAMA	3.10	2.59	2.79	.20

35 COLOMBIA	2.01	2.32	2.64	.31
36 TUNISIA	2.26	2.21	2.62	.40
37 PORTUGAL	3.63	.45	1.13	.68
38 COSTA RICA	1.35	2.73	3.43	.69
39 MAURITIUS	1.75	1.66	2.75	1.08
40 KOREA, SOUTH	5.51	1.95	2.75	.79
41 ECUADOR	2.38	2.89	2.76	-.13
42 PERU	.96	2.65	2.72	.07
43 GUATEMALA	1.45	2.91	2.48	-.42
44 TURKEY	3.45	2.42	1.75	-.66
45 DOM. REP	1.89	2.61	2.85	.23
46 BOTSWANA	7.08	3.24	2.43	-.81
47 EGYPT	4.38	2.49	2.21	-.27
48 PARAGUAY	2.36	2.88	2.98	.10
49 CONGO	3.63	2.81	1.94	-.87
50 MOROCCO	2.86	2.52	2.85	.32
51 NICARAGUA	-.09	2.98	3.09	.11
52 SRI LANKA	1.14	1.88	2.02	.14
53 JAMAICA	.36	1.46	2.05	.59
54 BOLIVIA	.99	2.53	2.16	-.37
55 PHILIPPINES	2.02	2.75	2.52	-.22
56 THAILAND	3.82	2.61	2.69	.07
57 PAKISTAN	2.78	3.01	2.56	-.45
58 EL SALVADOR	.23	2.43	3.17	.74
59 CAMEROON	3.82	2.69	1.71	-.97
60 INDONESIA	3.32	2.19	2.16	-.03
61 HONDURAS	1.64	3.32	3.12	-.20
62 IVORY COAST	2.16	4.04	2.72	-1.32
63 ZIMBABWE	1.43	3.42	3.06	-.35
64 PA N. GUINEA	1.93	2.44	1.94	-.49
65 SUDAN	-.02	2.73	2.39	-.34
66 NIGERIA	-.50	2.74	1.64	-1.09
67 MAURITANIA	.43	2.42	2.09	-.33
68 SIERRA LEONE	1.15	1.89	.94	-.95
69 SENEGAL	-.10	2.58	2.66	.07
70 LIBERIA	.08	2.97	2.46	-.51

71 BANGLADESH	1.15	2.65	1.95	-.70
72 BENIN	.50	2.81	1.84	-.96
73 ZAMBIA	-1.42	3.15	2.81	-.33
74 SOMALIA	.13	3.03	2.46	-.57
75 GHANA	-.19	2.60	2.15	-.45
76 KENYA	1.60	3.82	3.47	-.35
77 ANGOLA	-1.32	2.35	1.90	-.45
78 INDIA	1.40	2.26	1.72	-.53
79 NEPAL	1.60	2.32	1.60	-.72
80 TOGO	2.32	2.89	2.31	-.57
81 MADAGASCAR	-.95	2.70	1.88	-.81
82 MOZAMBIQUE	-1.52	2.47	2.59	.12
83 BURMA	2.73	2.14	2.07	-.07
84 CHAD	-1.26	1.99	1.60	-.39
85 RWANDA	1.13	3.20	2.79	-.40
86 CEN AFRICA	.24	1.99	1.16	-.82
87 MALAWAI	1.62	3.03	2.29	-.73
88 MALI	-.06	2.34	1.92	-.41
89 NIGER	.64	2.79	2.12	-.66
90 BURKINA FASO	2.28	2.27	1.75	-.52
91 BURUNDI	1.05	2.03	1.52	-.50
92 TANZANIA	2.60	3.27	2.77	-.49
93 ZAIRE	.65	2.69	1.78	-.90
94 UGANDA	.71	3.27	3.14	-.13
95 ETHIOPIA	1.41	2.56	2.05	-.51

		σ_k	σ_h	P(60)	P(88)	SER
1	USA	17.16	24.44	40.49	48.76	99
2	CANADA	22.89	27.63	37.26	50.18	103
3	SWITZERLAND	30.22	13.48	46.71	48.83	63
4	NORWAY	32.78	24.70	39.26	49.75	97
5	NETHERLANDS	23.97	28.74	35.48	40.88	102
6	AUSTRALIA	28.21	23.41	40.57	46.75	95
7	ITALY	27.91	18.16	41.28	40.20	75
8	FRANCE	25.87	22.21	43.21	44.91	96
9	BELGIUM	22.96	24.91	38.52	41.82	96
10	ISRAEL	26.32	21.19	35.85	38.79	76
11	SWEDEN	22.65	18.98	43.72	51.28	83
12	GERMANY	26.89	15.67	47.22	48.07	74
13	NEW ZEALAND	21.96	22.80	37.26	45.64	85
14	AUSTRIA	27.52	16.45	48.01	46.84	79
15	FINLAND	34.22	22.32	45.68	51.09	102
16	UK	18.12	19.23	46.27	48.46	89
17	DENMARK	27.81	22.56	45.64	55.01	103
18	JAPAN	30.95	20.20	47.51	50.00	96
19	SINGAPORE	29.24	21.65	32.78	47.92	71
20	TRIN&TOB	18.67	20.98	36.21	38.59	76
21	HONG KONG	20.89	17.72	38.93	53.10	69
22	SPAIN	26.21	23.96	37.97	36.30	91
23	VENEZUELA	16.47	14.14	31.82	34.19	45
24	MEXICO	19.63	19.01	28.92	34.26	55
25	IRELAND	26.44	24.31	39.47	40.12	96
26	GREECE	25.41	21.16	40.63	38.11	86
27	ALGERIA	26.00	19.29	26.43	22.69	51
28	SOUTH AFRICA	25.48	7.10	35.19	34.66	25
29	MALAYSIA	28.69	15.31	34.59	39.57	53
30	URUGUAY	15.74	17.26	40.54	39.84	70
31	ARGENTINA	11.77	17.79	39.33	35.79	70
32	BRAZIL	19.86	10.88	32.15	36.57	35
33	CHILE	13.32	21.17	32.57	35.70	69
34	PANAMA	24.82	17.73	33.27	35.08	59

35 COLOMBIA	17.19	16.52	30.25	32.97	50
36 TUNISIA	14.89	13.93	27.97	31.28	39
37 PORTUGAL	23.65	12.36	38.00	45.93	47
38 COSTA RICA	14.19	13.60	30.14	36.44	41
39 MAURITIUS	12.32	17.17	29.69	39.98	51
40 KOREA, SOUTH	24.74	28.10	33.80	42.00	95
41 ECUADOR	24.84	17.37	31.64	30.52	55
42 PERU	15.87	20.32	31.98	32.62	65
43 GUATEMALA	8.38	5.31	31.97	28.47	17
44 TURKEY	20.99	8.27	50.75	42.29	42
45 DOM. REP	14.75	17.83	28.03	29.88	50
46 BOTSWANA	23.85	6.64	43.65	35.63	29
47 EGYPT	6.21	21.33	29.05	26.92	62
48 PARAGUAY	11.35	9.68	32.00	32.95	31
49 CONGO	14.30	18.86	46.10	37.02	87
50 MOROCCO	8.71	11.03	28.08	30.69	31
51 NICARAGUA	18.69	13.17	29.59	30.46	39
52 SRI LANKA	21.20	17.54	35.89	37.24	63
53 JAMAICA	21.58	14.14	40.99	48.02	58
54 BOLIVIA	16.77	10.71	34.53	31.21	37
55 PHILIPPINES	19.08	17.03	38.15	35.84	65
56 THAILAND	14.90	5.89	50.92	52.04	30
57 PAKISTAN	15.47	6.99	34.32	30.35	24
58 EL SALVADOR	7.70	7.35	32.62	39.93	24
59 CAMEROON	10.26	4.70	48.83	37.42	23
60 INDONESIA	19.77	9.96	39.14	38.91	39
61 HONDURAS	13.13	11.28	31.90	30.18	36
62 IVORY COAST	9.81	3.70	53.99	37.73	20
63 ZIMBABWE	17.55	10.64	44.14	40.05	47
64 PA N. GUINEA	23.92	2.78	53.95	47.05	15
65 SUDAN	1.78	5.40	35.18	32.06	19
66 NIGERIA	11.72	2.61	110.85	82.07	29
67 MAURITANIA	13.26	3.25	36.82	33.61	12
68 SIERRA LEONE	2.24	3.66	46.36	36.05	17
69 SENEGAL	7.21	3.09	42.05	42.92	13
70 LIBERIA	28.82	5.50	41.80	36.75	23

71	BANGLADESH	5.87	5.30	33.91	28.67	18
72	BENIN	5.52	3.26	61.31	47.12	20
73	ZAMBIA	28.39	5.24	36.19	33.06	19
74	SOMALIA	10.01	4.10	41.39	35.43	17
75	GHANA	7.59	8.98	43.41	38.34	39
76	KENYA	14.44	4.48	44.55	40.51	20
77	ANGOLA	11.83	2.69	48.15	43.20	13
78	INDIA	16.51	7.90	44.26	38.17	35
79	NEPAL	9.86	5.09	49.06	41.15	25
80	TOGO	16.72	4.52	46.36	39.61	21
81	MADAGASCAR	8.65	7.04	51.12	42.63	36
82	MOZAMBIQUE	12.43	1.33	52.46	54.24	7
83	BURMA	11.58	5.22	45.89	45.19	24
84	CHAD	15.10	1.52	39.26	35.65	6
85	RWANDA	4.54	.35	55.86	49.99	2
86	CEN AFRICA	8.33	2.15	60.37	48.03	13
87	MALAWAI	11.75	.80	49.74	40.69	4
88	MALI	6.40	1.52	39.44	35.16	6
89	NIGER	8.75	1.01	59.09	49.25	6
90	BURKINA FASO	16.67	.95	52.55	46.80	5
91	BURUNDI	7.87	.83	60.23	52.35	5
92	TANZANIA	18.79	.54	55.05	48.07	3
93	ZAIRE	9.53	11.98	47.54	37.15	57
94	UGANDA	3.96	1.61	49.52	48.04	8
95	ETHIOPIA	4.72	2.34	51.17	44.98	12

	YL(60)	YL(88)	SER	AV
1 USA	24650	37608	99	39.5
2 CANADA	20816	32421	103	37.5
3 SWITZERLAND	19935	33080	63	38.4
4 NORWAY	13863	30103	97	40.4
5 NETHERLANDS	15745	28050	102	36.6
6 AUSTRALIA	17753	28490	95	37.0
7 ITALY	10598	29201	75	36.7
8 FRANCE	12367	27140	96	39.5
9 BELGIUM	13516	27481	96	38.9
10 ISRAEL	11024	24249	76	37.5
11 SWEDEN	14821	25330	83	39.7
12 GERMANY	12786	26219	74	37.6
13 NEW ZEALAND	19378	21609	85	36.8
14 AUSTRIA	9322	23907	79	37.8
15 FINLAND	10326	24190	102	38.5
16 UK	13766	24725	89	38.9
17 DENMARK	12920	21969	103	38.2
18 JAPAN	5684	24417	96	36.6
19 SINGAPORE	7334	21735	71	34.0
20 TRIN&TOB	13128	14671	76	35.5
21 HONG KONG	5966	25006	69	35.9
22 SPAIN	7113	20398	91	38.1
23 VENEZUELA	12252	16719	45	33.8
24 MEXICO	9923	14581	55	34.4
25 IRELAND	8141	15546	96	39.4
26 GREECE	4647	15366	86	36.5
27 ALGERIA	6340	12011	51	34.3
28 SOUTH AFRICA	8477	12781	25	34.3
29 MALAYSIA	5152	11945	53	34.8
30 URUGUAY	10855	12948	70	36.5
31 ARGENTINA	8595	11258	70	36.0
32 BRAZIL	4367	12142	35	32.8
33 CHILE	9524	11480	69	34.9
34 PANAMA	4595	10168	59	34.2

35 COLOMBIA	6192	10818	50	33.2
36 TUNISIA	4982	9336	39	35.5
37 PORTUGAL	4257	11583	47	36.2
38 COSTA RICA	7147	10421	41	32.8
39 MAURITIUS	7115	11570	51	34.4
40 KOREA, SOUTH	2730	12275	95	34.3
41 ECUADOR	4614	8933	55	32.9
42 PERU	6659	8725	65	34.6
43 GUATEMALA	5213	7822	17	32.5
44 TURKEY	3288	8507	42	34.4
45 DOM. REP	4373	7388	50	34.0
46 BOTSWANA	1081	6402	29	33.5
47 EGYPT	1917	6373	62	33.5
48 PARAGUAY	3744	7210	31	33.6
49 CONGO	2368	5989	87	35.3
50 MOROCCO	3040	6711	31	32.9
51 NICARAGUA	5921	5773	39	32.0
52 SRI LANKA	3869	5259	63	35.2
53 JAMAICA	4461	4918	58	36.5
54 BOLIVIA	3306	4362	37	32.4
55 PHILIPPINES	3100	5431	65	32.7
56 THAILAND	1934	5532	30	32.3
57 PAKISTAN	2389	5162	24	34.8
58 EL SALVADOR	4000	4269	24	32.9
59 CAMEROON	1507	4314	23	33.6
60 INDONESIA	1880	4404	39	33.7
61 HONDURAS	2820	4458	36	31.7
62 IVORY COAST	1890	3445	20	31.9
63 ZIMBABWE	2122	3158	47	32.6
64 PA N. GUINEA	2104	3603	15	32.6
65 SUDAN	2771	2754	19	31.7
66 NIGERIA	3212	2786	29	33.7
67 MAURITANIA	2519	2846	12	32.3
68 SIERRA LEONE	1878	2561	17	33.3
69 SENEGAL	2700	2623	13	32.3
70 LIBERIA	2308	2357	23	33.9

71 BANGLADESH	1831	2441	18	32.8
72 BENIN	1752	2020	20	32.1
73 ZAMBIA	3235	2162	19	32.3
74 SOMALIA	2151	2232	17	32.3
75 GHANA	2416	2287	39	32.6
76 KENYA	1425	2226	20	31.8
77 ANGOLA	2716	1944	13	33.5
78 INDIA	1394	2059	35	33.1
79 NEPAL	1190	1771	25	31.5
80 TOGO	886	1685	21	31.5
81 MADAGASCAR	1981	1426	36	31.8
82 MOZAMBIQUE	2607	1694	7	33.2
83 BURMA	743	1458	24	33.4
84 CHAD	1999	1455	6	33.7
85 RWANDA	963	1322	2	30.5
86 CEN AFRICA	1335	1428	13	32.3
87 MALAWAI	850	1334	4	32.8
88 MALI	1371	1348	6	31.4
89 NIGER	1022	1222	6	30.9
90 BURKINA FASO	719.00	1209	5	31.9
91 BURUNDI	785.00	1054	5	32.0
92 TANZANIA	494.00	1015	3	32.1
93 ZAIRE	797	958	57	33.0
94 UGANDA	749	895	8	32.5
95 ETHIOPIA	512	738	12	32.0

		CU60	CU88	y^*	k^*	h^*
1	USA	100.00	100.00	11.24	31.61	45.03
2	CANADA	84.44	86.20	15.66	56.43	68.13
3	SWITZERLAND	80.87	87.96	12.47	65.99	29.44
4	NORWAY	56.23	80.04	26.05	153.17	115.44
5	NETHERLANDS	63.87	74.58	19.79	80.44	96.46
6	AUSTRALIA	72.02	75.75	14.67	61.73	51.23
7	ITALY	42.99	77.64	16.85	85.80	55.85
8	FRANCE	50.17	72.16	17.55	79.38	68.17
9	BELGIUM	54.83	73.07	20.50	89.14	96.75
10	ISRAEL	44.72	64.47	9.43	32.30	26.01
11	SWEDEN	60.12	67.35	14.76	61.95	51.91
12	GERMANY	51.87	69.71	14.74	74.19	43.23
13	NEW ZEALAND	78.61	57.45	12.96	45.78	47.54
14	AUSTRIA	37.81	63.56	16.41	86.00	51.42
15	FINLAND	41.89	64.32	26.26	166.68	108.74
16	UK	55.84	65.74	12.44	42.62	45.24
17	DENMARK	52.41	58.41	21.46	110.39	89.57
18	JAPAN	23.05	64.92	17.69	92.13	60.14
19	SINGAPORE	29.75	57.79	13.81	59.66	44.19
20	TRIN&TOB	53.25	39.01	8.75	24.42	27.45
21	HONG KONG	24.20	66.49	7.06	20.37	17.28
22	SPAIN	28.85	54.23	18.12	80.69	73.78
23	VENEZUELA	49.70	44.45	3.26	6.35	5.45
24	MEXICO	40.25	38.77	6.08	15.24	14.76
25	IRELAND	33.02	41.33	18.88	85.59	78.72
26	GREECE	18.85	40.85	16.74	75.08	62.53
27	ALGERIA	25.72	31.93	8.11	26.82	19.90
28	SOUTH AFRICA	34.38	33.98	3.41	11.93	3.32
29	MALAYSIA	20.90	31.76	7.56	28.47	15.20
30	URUGUAY	44.03	34.42	8.65	24.30	26.66
31	ARGENTINA	34.86	29.93	4.91	8.87	13.41
32	BRAZIL	17.71	32.28	3.84	10.17	5.57
33	CHILE	38.63	30.52	6.06	11.83	18.81
34	PANAMA	18.64	27.03	7.63	24.98	17.84

35 COLOMBIA	25.11	28.76	5.28	12.40	11.92
36 TUNISIA	20.21	24.82	3.98	8.22	7.70
37 PORTUGAL	17.26	30.79	9.81	42.55	22.25
38 COSTA RICA	28.99	27.70	3.22	5.91	5.67
39 MAURITIUS	28.86	30.76	4.76	8.80	12.27
40 KOREA, SOUTH	11.07	32.63	14.36	51.08	58.02
41 ECUADOR	18.71	23.75	6.92	21.76	15.23
42 PERU	27.01	23.19	5.50	11.42	14.62
43 GUATEMALA	21.14	20.79	.71	.75	.47
44 TURKEY	13.33	22.62	3.15	8.91	3.51
45 DOM. REP	17.74	19.64	4.53	8.77	10.60
46 BOTSWANA	4.38	17.02	2.33	6.75	1.88
47 EGYPT	7.77	16.94	2.36	1.95	6.72
48 PARAGUAY	15.18	19.17	1.77	2.54	2.17
49 CONGO	9.60	15.92	4.42	8.10	10.68
50 MOROCCO	12.33	17.84	1.69	1.96	2.48
51 NICARAGUA	24.02	15.35	3.86	9.05	6.38
52 SRI LANKA	15.69	13.98	7.86	24.21	20.04
53 JAMAICA	18.09	13.07	7.31	24.43	16.02
54 BOLIVIA	13.41	11.59	3.16	7.03	4.49
55 PHILIPPINES	12.57	14.44	5.40	13.31	11.88
56 THAILAND	7.84	14.70	1.51	2.95	1.16
57 PAKISTAN	9.69	13.72	1.68	3.24	1.46
58 EL SALVADOR	16.22	11.35	1.02	1.06	1.01
59 CAMEROON	6.11	11.47	.81	1.09	.50
60 INDONESIA	7.62	11.71	3.80	10.47	5.27
61 HONDURAS	11.44	11.85	2.13	3.36	2.89
62 IVORY COAST	7.66	9.16	.44	.48	.18
63 ZIMBABWE	8.60	8.39	2.63	5.48	3.32
64 PA N. GUINEA	8.53	9.58	1.20	3.85	.44
65 SUDAN	11.24	7.32	.16	.03	.11
66 NIGERIA	13.03	7.40	.51	.77	.17
67 MAURITANIA	10.21	7.56	.78	1.40	.34
68 SIERRA LEONE	7.61	6.80	.17	.05	.09
69 SENEGAL	10.95	6.97	.38	.36	.15
70 LIBERIA	9.36	6.26	2.49	9.02	1.72

71 BANGLADESH	7.42	6.49	.53	.40	.36
72 BENIN	7.10	5.37	.29	.20	.12
73 ZAMBIA	13.12	5.74	2.24	7.81	1.44
74 SOMALIA	8.72	5.93	.63	.79	.32
75 GHANA	9.80	6.08	1.17	1.17	1.39
76 KENYA	5.78	5.91	.83	1.36	.42
77 ANGOLA	11.01	5.16	.59	.95	.21
78 INDIA	5.65	5.47	2.47	5.62	2.69
79 NEPAL	4.82	4.70	.93	1.26	.65
80 TOGO	3.59	4.48	1.21	2.57	.69
81 MADAGASCAR	8.03	3.79	1.02	1.15	.93
82 MOZAMBIQUE	10.57	4.50	.29	.49	.05
83 BURMA	3.01	3.87	1.18	1.92	.87
84 CHAD	8.10	3.86	.47	1.02	.10
85 RWANDA	3.90	3.51	.02	.01	.00105
86 CEN AFRICA	5.41	3.79	.36	.43	.11
87 MALAWAI	3.44	3.54	.14	.21	.01
88 MALI	5.56	3.58	.18	.15	.03
89 NIGER	4.14	3.24	.14	.16	.01
90 BURKINA FASO	2.91	3.21	.30	.68	.03
91 BURUNDI	3.18	2.80	.13	.14	.01
92 TANZANIA	2.00	2.69	.14	.33	.00983
93 ZAIRE	3.23	2.54	1.93	2.39	3.01
94 UGANDA	3.03	2.37	.09	.04	.01
95 ETHIOPIA	2.07	1.96	.19	.12	.06

IN 1991 REEDS VERSCHENEN

466 Prof.Dr. Th.C.M.J. van de Klundert - Prof.Dr. A.B.T.M. van Schaik
Economische groei in Nederland in een internationaal perspectief

467 Dr. Sylvester C.W. Eijffinger
The convergence of monetary policy - Germany and France as an example

468 E. Nijssen
Strategisch gedrag, planning en prestatie. Een inductieve studie binnen de computerbranche

469 Anne van den Nouweland, Peter Borm, Guillermo Owen and Stef Tijs
Cost allocation and communication

470 Drs. J. Grazell en Drs. C.H. Veld
Motieven voor de uitgifte van converteerbare obligatieleningen en warrant-obligatieleningen: een agency-theoretische benadering

471 P.C. van Batenburg, J. Kriens, W.M. Lammerts van Bueren and R.H. Veenstra
Audit Assurance Model and Bayesian Discovery Sampling

472 Marcel Kerkhofs
Identification and Estimation of Household Production Models

473 Robert P. Gilles, Guillermo Owen, René van den Brink
Games with Permission Structures: The Conjunctive Approach

474 Jack P.C. Kleijnen
Sensitivity Analysis of Simulation Experiments: Tutorial on Regression Analysis and Statistical Design

475 C.P.M. van Hoesel
An $O(nlogn)$ algorithm for the two-machine flow shop problem with controllable machine speeds

476 Stephan G. Vanneste
A Markov Model for Opportunity Maintenance

477 F.A. van der Duyn Schouten, M.J.G. van Eijs, R.M.J. Heuts
Coordinated replenishment systems with discount opportunities

478 A. van den Nouweland, J. Potters, S. Tijs and J. Zarzuelo
Cores and related solution concepts for multi-choice games

479 Drs. C.H. Veld
Warrant pricing: a review of theoretical and empirical research

480 E. Nijssen
De Miles and Snow-typologie: Een exploratieve studie in de meubelbranche

481 Harry G. Barkema
Are managers indeed motivated by their bonuses?

482 Jacob C. Engwerda, André C.M. Ran, Arie L. Rijkeboer
Necessary and sufficient conditions for the existence of a positive definite solution of the matrix equation $X + A^T X^{-1} A = I$

483 Peter M. Kort
A dynamic model of the firm with uncertain earnings and adjustment costs

484 Raymond H.J.M. Gradus, Peter M. Kort
Optimal taxation on profit and pollution within a macroeconomic framework

485 René van den Brink, Robert P. Gilles
Axiomatizations of the Conjunctive Permission Value for Games with Permission Structures

486 A.E. Brouwer & W.H. Haemers
The Gewirtz graph - an exercise in the theory of graph spectra

487 Pim Adang, Bertrand Melenberg
Intratemporal uncertainty in the multi-good life cycle consumption model: motivation and application

488 J.H.J. Roemen
The long term elasticity of the milk supply with respect to the milk price in the Netherlands in the period 1969-1984

489 Herbert Hamers
The Shapley-Entrance Game

490 Rezaul Kabir and Theo Vermaelen
Insider trading restrictions and the stock market

491 Piet A. Verheyen
The economic explanation of the jump of the co-state variable

492 Drs. F.L.J.W. Manders en Dr. J.A.C. de Haan
De organisatorische aspecten bij systeemontwikkeling
een beschouwing op besturing en verandering

493 Paul C. van Batenburg and J. Kriens
Applications of statistical methods and techniques to auditing and accounting

494 Ruud T. Frambach
The diffusion of innovations: the influence of supply-side factors

495 J.H.J. Roemen
A decision rule for the (des)investments in the dairy cow stock

496 Hans Kremers and Dolf Talman
An SLSPP-algorithm to compute an equilibrium in an economy with linear production technologies

497 L.W.G. Strijbosch and R.M.J. Heuts
Investigating several alternatives for estimating the compound lead time demand in an (s,Q) inventory model

498 Bert Bettonvil and Jack P.C. Kleijnen
Identifying the important factors in simulation models with many factors

499 Drs. H.C.A. Roest, Drs. F.L. Tijssen
Beheersing van het kwaliteitsperceptieproces bij diensten door middel van keurmerken

500 B.B. van der Genugten
Density of the F-statistic in the linear model with arbitrarily normal distributed errors

501 Harry Barkema and Sytse Douma
The direction, mode and location of corporate expansions

502 Gert Nieuwenhuis
Bridging the gap between a stationary point process and its Palm distribution

503 Chris Veld
Motives for the use of equity-warrants by Dutch companies

504 Pieter K. Jagersma
Een etiologie van horizontale internationale ondernemingsexpansie

505 B. Kaper
On M-functions and their application to input-output models

506 A.B.T.M. van Schaik
Produktiviteit en Arbeidsparticipatie

507 Peter Borm, Anne van den Nouweland and Stef Tijs
Cooperation and communication restrictions: a survey

508 Willy Spanjers, Robert P. Gilles, Pieter H.M. Ruys
Hierarchical trade and downstream information

509 Martijn P. Tummers
The Effect of Systematic Misperception of Income on the Subjective Poverty Line

510 A.G. de Kok
Basics of Inventory Management: Part 1
Renewal theoretic background

511 J.P.C. Blanc, F.A. van der Duyn Schouten, B. Pourbabai
Optimizing flow rates in a queueing network with side constraints

512 R. Peeters
On Coloring j-Unit Sphere Graphs

513 Drs. J. Dagevos, Drs. L. Oerlemans, Dr. F. Boekema
Regional economic policy, economic technological innovation and networks

514 Erwin van der Krabben
Het functioneren van stedelijke onroerend-goed-markten in Nederland - een theoretisch kader

515 Drs. E. Schaling
European central bank independence and inflation persistence

516 Peter M. Kort
Optimal abatement policies within a stochastic dynamic model of the firm

517 Pim Adang
Expenditure versus consumption in the multi-good life cycle consumption model

518 Pim Adang
Large, infrequent consumption in the multi-good life cycle consumption model

519 Raymond Gradus, Sjak Smulders
Pollution and Endogenous Growth

520 Raymond Gradus en Hugo Keuzenkamp
Arbeidsongeschiktheid, subjectief ziektegevoel en collectief belang

521 A.G. de Kok
Basics of inventory management: Part 2
The (R,S)-model

522 A.G. de Kok
Basics of inventory management: Part 3
The (b,Q)-model

523 A.G. de Kok
Basics of inventory management: Part 4
The (s,S)-model

524 A.G. de Kok
Basics of inventory management: Part 5
The (R,b,Q)-model

525 A.G. de Kok
Basics of inventory management: Part 6
The (R,s,S)-model

526 Rob de Groof and Martin van Tuijl
Financial integration and fiscal policy in interdependent two-sector economies with real and nominal wage rigidity

527 A.G.M. van Eijs, M.J.G. van Eijs, R.M.J. Heuts
Gecoördineerde bestelsystemen
een management-georiënteerde benadering

528 M.J.G. van Eijs
Multi-item inventory systems with joint ordering and transportation decisions

529 Stephan G. Vanneste
Maintenance optimization of a production system with buffercapacity

530 Michel R.R. van Bremen, Jeroen C.G. Zijlstra
Het stochastische variantie optiewaarderingsmodel

531 Willy Spanjers
Arbitrage and Walrasian Equilibrium in Economies with Limited Information

IN 1992 REEDS VERSCHENEN

532 F.G. van den Heuvel en M.R.M. Turlings
Privatisering van arbeidsongeschiktheidsregelingen
Refereed by Prof.Dr. H. Verbon

533 J.C. Engwerda, L.G. van Willigenburg
LQ-control of sampled continuous-time systems
Refereed by Prof.dr. J.M. Schumacher

534 J.C. Engwerda, A.C.M. Ran & A.L. Rijkeboer
Necessary and sufficient conditions for the existence of a positive definite solution of the matrix equation $X + A^*X^{-1}A = Q$.
Refereed by Prof.dr. J.M. Schumacher

535 Jacob C. Engwerda
The indefinite LQ-problem: the finite planning horizon case
Refereed by Prof.dr. J.M. Schumacher

536 Gert-Jan Otten, Peter Borm, Ton Storcken, Stef Tijs
Effectivity functions and associated claim game correspondences
Refereed by Prof.dr. P.H.M. Ruys

537 Jack P.C. Kleijnen, Gustav A. Alink
Validation of simulation models: mine-hunting case-study
Refereed by Prof.dr.ir. C.A.T. Takkenberg

538 V. Feltkamp and A. van den Nouweland
Controlled Communication Networks
Refereed by Prof.dr. S.H. Tijs